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SOIL CONSERVATION SERVICE-RESEARCH
WASHINGTON 25, D.C.

In cooperation with the
Illinois, Iowa, Minnesota and Wisconsin Agricultural Experiment Stations

RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES IN THE UPPER MISSISSIPPI VALLEY UPLAND LOESSIAL AREAS

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FOREWORD

This publication is one of a series containing information for the hydrologic design of conservation structures and practices in important agricultural areas where hydrologic studies have been made by the Soil Conservation Service. The information and procedures contained in these publications are based on rainfall, runoff, and other hydrologic data obtained from the runoff studies and from other research projects of the Service conducted in cooperation with State agricultural experiment stations. United States Weather Bureau records of precipitation and published and unpublished records of stream flow of the United States Geological Survey, and available records from other sources are utilized in the preparation of these publications.

Records of runoff from small watersheds, within the areas included in this publication, are still very limited as to range in watershed size and length of record. More definite information is needed on the relation of rates of runoff to size of drainage area and the effect of crop cover on rates and amounts of runoff from watersheds of various sizes. Rates of runoff from individual terraces of various lengths and horizontal spacings and under several crop covers and rotations are necessary before recommendations can be made for terraced areas. Pending additional research, such data as are now available must be utilized to fill the present-day needs. Values presented in this report must be considered tentative, however, and subject to revision as additional information becomes available.

M L Nichols

M. L. Nichols
Chief of Research

ACKNOWLEDGMENTS

The establishment of the runoff studies and the collection of the records utilized in the preparation of this report involved the work of the author and other members of the Division of Drainage and Water Control, Soil Conservation Service--Research. The construction of the measuring devices and field observations for the Fennimore, Wis., studies were carried out by the Operations personnel assigned to this work by Region 3 of the Service. Records for the La Crosse Experiment Station watersheds were furnished by O. E. Hays, project supervisor, Soil Conservation Service--Research. Records of runoff from the larger drainage areas were furnished by the district offices of the United States Geological Survey. In establishing the areas of application, the author had the benefit of discussions with Operations technicians of the Regional and State offices of the Soil Conservation Service and members of the various agricultural experiment stations. The field studies and the analysis of the records were carried out under cooperative project agreements and working plans approved by the Agricultural Experiment Stations of Illinois, Iowa, Minnesota, and Wisconsin.

This report was reviewed by L. A. Jones, chief, Division of Drainage and Water Control, and by the technical staffs of the Illinois, Iowa, Minnesota, and Wisconsin Agricultural Experiment Stations and the Regional Office of Region 3 of the Soil Conservation Service. The author is indebted to the reviewers for their constructive criticisms. The guidance of D. B. Krimgold, soil conservationist, formerly of the Division of Drainage and Water Control, under whose immediate direction the studies were made, is gratefully acknowledged.

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RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES IN THE UPPER MISSISSIPPI VALLEY UPLAND LOESSIAL AREAS

By N. E. Minshall, agricultural engineer, Division of Drainage and Water Control, Research, Soil Conservation Service

INTRODUCTION

This report presents a brief history of the work and a detailed description of the watersheds, instrumentation, and procedures employed in the collection and compilation of data from the runoff studies near Fennimore, Wis. It outlines the area within which the information presented can be applied if proper care is exercised in evaluating the watershed characteristics. It also gives data for a group of the most intense storms on each of the watersheds and typical hydrographs indicating the effect of cover and antecedent moisture on rates of runoff.

The report outlines briefly the methods of analysis and presents, in both tabular and graphical form, recommended rates of runoff, from small agricultural watersheds, to be used in the design of conservation structures. It recognizes the fact that peak rates of runoff from small areas are of very short duration, thus making small amounts of storage effective in reducing these rates. The average flood-distribution graph and curve of total storm runoff are presented for the engineer's use in computing such reductions in peak rates.

The large differences in rates of runoff from pastured and cultivated watersheds are due to the ability of the soils in this area to absorb large amounts of rainfall of high intensity when the surface is protected by good vegetative cover. The values given are believed to be conservative and no factor of safety need be used in their application.

No recommendations are made for rates of runoff from individual terraces or terraced watersheds as the available data are far too meager to permit any logical analysis.

SOURCES OF DATA

Data included in this publication are generally applicable to upland areas, within the boundaries shown on the map of figure 1, page 2, in northwestern Illinois, northeastern Iowa, southeastern Minnesota, and southwestern Wisconsin. This area is mainly the unglaciated section of the Upper Mississippi River drainage basin. The extensive soils of this area are derived from three kinds of parent material; loess, a mixture of loess and limestone residuum, and glacial till. The soils of loessial origin are Tama, Fayette, and Clinton silt loams. Tama soils are dark colored, deep and moderately permeable. Fayette silt loam is deep and moderately permeable but has light colored surface soil. Clinton soils have heavier textured and less permeable subsoils than the Fayette soils. The Dubuque and Dodgeville soils are developed on material derived from a layer of loess less than 18 inches thick over limestone residuum. Where the loess covering is 18 to 36 inches thick a deep phase is mapped. These soils are shallow or moderately deep, depending on the thickness of the loess covering. They are medium textured and usually moderately permeable.

GENERAL AREA OF APPLICATION

FIGURE 1.

The Carrington soils are derived from friable glacial till. They have dark-colored surface layers like the Tama and Dodgeville soils and are deep and moderately permeable. Within this area records of runoff available as a basis for design of conservation structures and practices on small drainage basins are limited to those obtained by the Soil Conservation Service at La Crosse and Fennimore, Wis., and the Ralston Creek cooperative project of the State University of Iowa, Department of Agriculture, and the United States Geological Survey. Records obtained from these studies include:

1. Rainfall, runoff, soil and air temperatures, relative humidity, and cover and tillage for 9 years (1938-46) on four small watersheds 1 mile north of Fennimore, Wis. These areas are 22.8, 52.5, 171, and 330 acres, all in mixed crops. None of them had one single type of cover in any year.

2. Rainfall, runoff, soil loss, and cover and tillage records from three small watersheds on the Upper Mississippi Valley Experiment Station farm east of La Crosse, Wis.(*3*).1/ The watersheds include a 12-year record (1934-45) on a 2.33-acre unterraced cultivated watershed (UCW) farmed as a 3-year rotation of corn, grain, hay except for 1940-43 when the area was all in hay; a 9-year record (1937-45) on a 2.7-acre strip-cropped watershed (CW) with a 6-year rotation of corn, grain, 4 years hay; and a 12-year record (1934-45) on a 2.41-acre unterraced pasture watershed (UPW).

3. Rainfall, runoff, temperature, and cover and tillage for 22 years (1924-45) on a 1,926-acre Ralston Creek area near Iowa City.

United States Weather Bureau records of precipitation and temperature are available for more than 50 years at a number of stations within the area, with the longest continuous record of 95 years at Dubuque, Iowa.

Records of runoff for Gilmore Creek near Winona, Minn., with a drainage area of 8.95 square miles (1941-45), East Fork Galena River near Council Hill, Ill., with an area of 20.1 square miles (1941-45), Rapid Creek near Iowa City, Iowa, with an area of 24.5 square miles (1938-45), Coon Creek at Coon Valley, Wis.,(*4*), with an area of 77.2 square miles (1934-40), Little Maquoketa River near Durango, Iowa, with an area of 130 square miles (1938-45), Platte River near Rockville, Wis., with an area of 137 square miles (1938-45), Yellow River at Ion, Iowa, drainage area 224 square miles (1935-45), and Grant River near Burton, Wis., with drainage area 257 square miles (1935-45) were collected by the United States Geological Survey.

Short records of runoff of 10 years or less are not sufficient for a complete analysis upon which to base final design recommendations. However, since there is an urgent need for this information and longer records on these soil types are not available, it becomes necessary to make the best possible estimates from the data obtained thus

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1/ Italic numbers in parentheses refer to Literature Cited, p. 30.

far. Some of the recommendations must necessarily be based on the judgment of the author as exact relationships seldom exist in hydrology.

DESCRIPTION OF WATERSHEDS

The runoff studies on the Fennimore, Wis., Demonstration Project consist of four watersheds with areas of 22.8, 52.5, 171, and 330 acres, located about 1 mile north of Fennimore. The three smaller areas are entirely within the 330-acre watershed. The topography, soils, slopes, and erosion of these areas are shown on the maps of figures 2 and 3, pages 5 and 6.

The table of watershed characteristics (table 1, p. 8) was compiled in an attempt to express as many of the permanent characteristics as possible in a simple manner. This table will enable the users of the runoff data to determine the extent to which data obtained from a given watershed must be modified in applying them to other drainage areas. The definitions given below were established to insure uniform results from all the runoff projects (5). With these definitions the characteristics of any drainage area can be determined with sufficient accuracy from a reasonably well-prepared topographic map which shows the extent of the principal waterways.

(1), (2), and (8) require no definition.

(3) Prevailing slopes are slopes which exist on 30 percent or more of the watershed. Two or three values are given if the slopes fall into that many groups each applying to 30 percent or more of the total area.

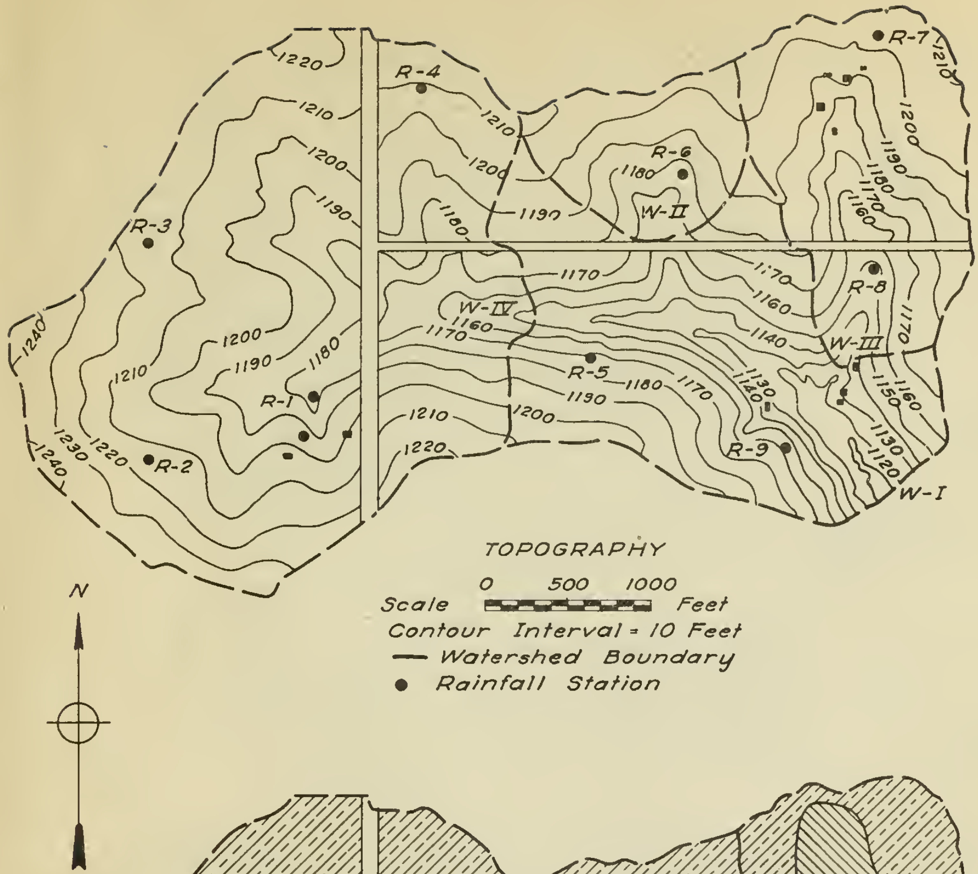
(4) Range in slopes is the range between the flattest and steepest slopes.

(5) Length of Principal Waterway is the length of the major waterway measured along the thread of the stream from the weir to a point at which water concentrates sufficiently to produce channel flow under flood conditions. These points were determined from a careful study of the watersheds during runoff. In cases where the watershed is divided by two main waterways, which join near the weir, each draining over 30 percent of the area, the length of both is recorded and designated as "A" and "B".

(6) Average Slope of Principal Waterway is determined by dividing the difference in elevation at the beginning and end of the principal waterway by the length of the waterway in feet.

(7) Total Number of Waterways includes the principal waterway and all tributaries.

(9) Total Length of Waterways is the combined length of the principal waterway and all tributaries.



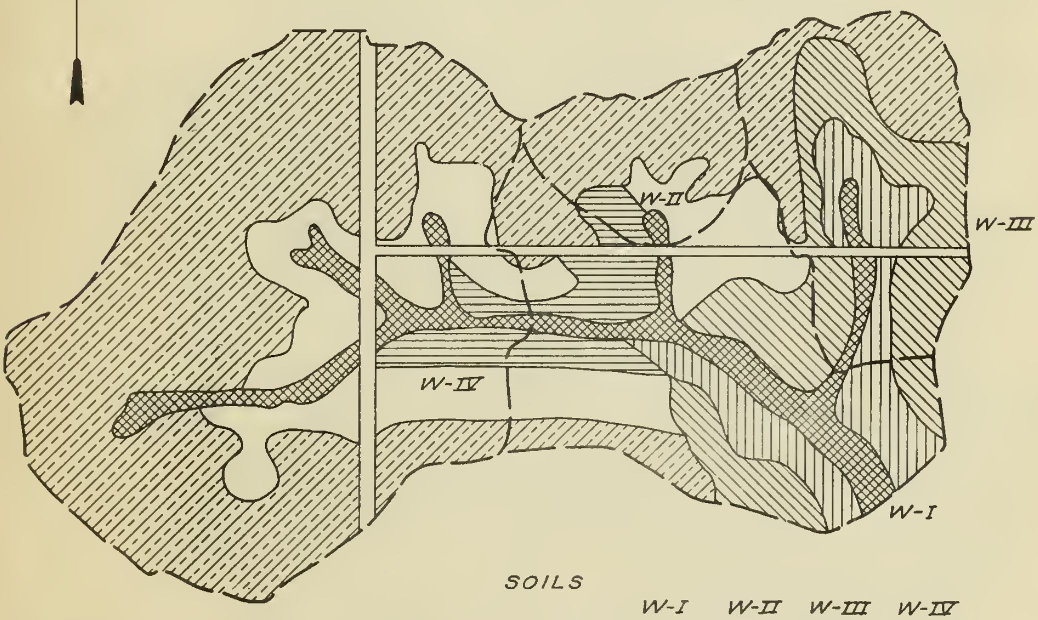
TOPOGRAPHY

Scale 0 500 1000 Feet

Contour Interval = 10 Feet

— Watershed Boundary

● Rainfall Station

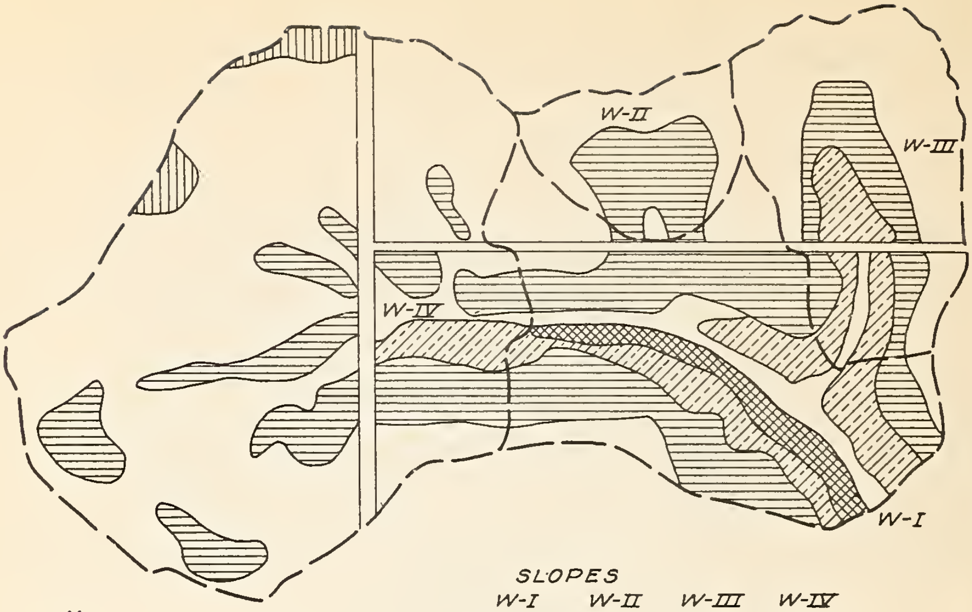


SOILS

	W-I %	W-II %	W-III %	W-IV %
Tama silt loam	50.1	72.8	34.1	69.5
Dubuque silt loam (deep phase)	12.3		44.1	
Dubuque silt loam (shallow phase)	7.1		17.0	
Dodgeville silt loam (deep phase)	17.1	16.6		20.6
Dodgeville silt loam (shallow phase)	5.7	8.5		3.7
Deposition	7.9	2.1	4.8	6.2

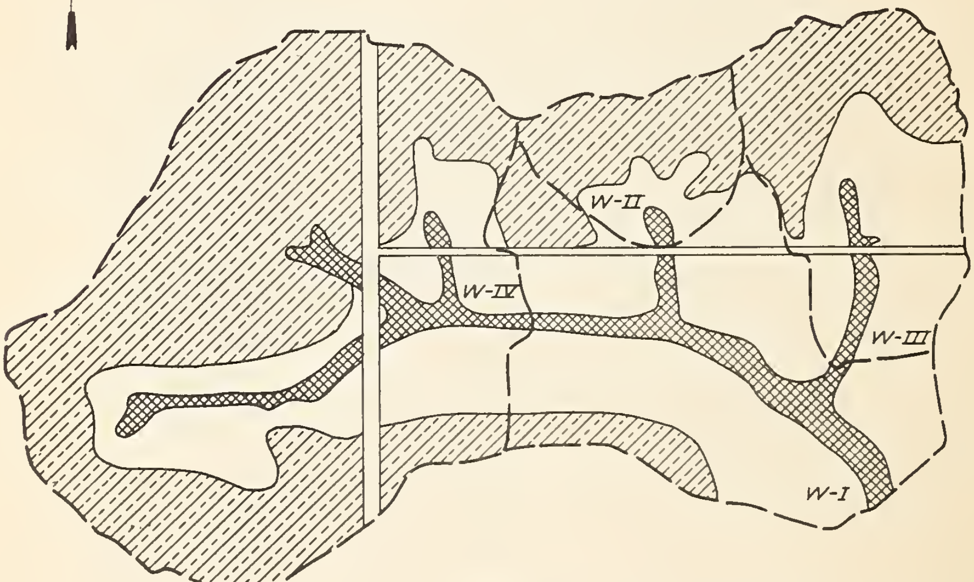
TOPOGRAPHY AND SOILS OF FENNIMORE WATERSHEDS

FIGURE 2.



SLOPES

	W-I %	W-II %	W-III %	W-IV %
0-2 %	1.5			2.8
2-6 %	62.1	52.0	60.0	74.5
6-10 %	24.8	48.0	23.6	19.9
10-15 %	9.2		16.4	2.8
15-20 %	2.4			



EROSION

	W-I %	W-II %	W-III %	W-IV %
(2) 25 to 50 % of surface soil lost	50.6	65.6	45.7	67.5
(3) 50 to 75 % of surface soil lost	41.5	32.3	49.5	26.3
+ Deposition from slopes above	7.9	2.1	4.8	6.2

SLOPES AND EROSION OF FENNIMORE WATERSHEDS

FIGURE 3.

(10) Drainage Density is the length of waterways per acre determined by dividing item 9 by the area of the watershed in acres.

(11) Form Factor is a dimensionless number serving as an index of the shape of the watershed. It is expressed by A/L^2 where A is the drainage area in square feet and L is the length of the watershed in feet measured in a straight line in the general direction of the principal waterway between the weir and the point at which this line crosses the divide. (A/L^2 is the reciprocal of L/W which is commonly used.)

(12) Soil Types

(a) Tama silt loam--Deep, dark-colored, medium-textured surface, moderately permeable loess soil developed under prairie vegetation. Loess over 36 inches in depth.

(b) Dubuque silt loam (deep phase) moderately deep, light-colored, medium-textured surface, moderately permeable subsoil, developed under timber vegetation. Underlain by limestone clay residuum at 18 to 36 inches.

(c) Dubuque silt loam (shallow phase) same as deep phase, except having the underlying limestone clay residuum at less than 18 inches.

(d) Dodgeville silt loam (deep phase) moderately deep, dark-colored, medium-textured surface, moderately permeable subsoil developed under prairie vegetation. Underlain by limestone clay residuum at 18 to 36 inches.

(e) Dodgeville silt loam (shallow phase) same as deep phase except having the underlying clay residuum at less than 18 inches.

(f) Deposition by erosion of surface soil from the sloping fields above.

The percentage of each watershed in the various land capability classes in accordance with the legend below is indicated in table 2, page 8.

Class 1, called ''Green land''--less than 2-percent slopes on deep silt loam or well-drained bottom lands.

TABLE 1.--*Watershed characteristics*

		W-I	W-II	W-III	W-IV
1	Size of drainage area—acres	330	22.8	52.5	171
2	Range in elevation--feet	1,105-1,247	1,158-1,212	1,124-1,211	1,146-1,247
3	Prevailing land slopes--percent	4 and 8	4 and 8	4 and 10	4 and 7
4	Range in land slopes--percent	1 to 20	1 to 10	2 to 20	1 to 12
5	Length of prin. waterway-feet	5,200	400	2,200	2,450
6	Average slope of prin. waterway, percent	1.8	5.0	3.5	2.2
7	Total number of waterways	6	2	2	4
8	Number of acres per waterway	55	11.4	26.2	42.8
9	Total length of waterways—feet	10,800	750	2,300	4,950
10	Drainage density (length of waterways, ft./acre)	33	32.8	44	28.9
11	Form factor A/L^2	0.54	1.10	0.46	0.78
12	Soil types—percent of area				
	a. Tama silt loam	50.1	72.8	34.1	69.5
	b. Dubuque silt loam (deep phase)	12.3		44.1	
	c. Dubuque silt loam (shallow phase)	7.1		17.0	
	d. Dodgeville silt loam (deep phase)	17.1	16.6		20.6
	e. Dodgeville silt loam (shallow phase)	5.7	8.5		3.7
	f. Deposition	7.9	2.1	4.8	6.2

TABLE 2.--*Land capabilities (percent of area)*

	W-I	W-II	W-III	W-IV
Class 1 "Green Land"	6.3	2.6	4.3	6.5
Class 2 "Yellow Land"	76.7	87.3	72.6	90.1
Class 3 "Red Land"	7.0	10.1	13.2	.9
Class 4 "Blue Land"	10.0		9.9	2.5

Class 2, called ''Yellow land''--rolling 2 to 6-percent slopes in deep silt loam subject to moderate erosion. Suitable for short rotations if strip-cropped on the contour or terraced.

Class 3, called ''Red land,'' sloping land, 6 to 15 percent on deep silt loam subject to moderate to severe erosion, or shallow soils. Suitable for long rotations and recommended for terracing.

Class 4, called ''Blue land''--over 15 percent slopes subject to severe erosion or wet bottom lands. Recommended for hay, permanent pasture, or very long rotations.

Watershed W-I, with an area of 330 acres, has a maximum length of 1 mile and an average width of one-half mile with a total difference in elevation of 142 feet. The form factor of 0.54 indicates an area whose length, along the main watercourse, is approximately twice its average width. Land slopes vary from 1 to 20 percent with prevailing slopes of 4 and 8 percent each, applying to approximately 30 percent of the area. The high value of 55 acres per waterway and the low drainage density of 33 feet per acre indicate there is a predominance of overland flow and that concentration of runoff from the area will be rather slow. Impervious areas within the watershed consist of U. S. Highway 61, a 30-foot-wide black-top pavement running north and south across the western part of the area; a gravel town road extending east from this road on the approximate center line of the area; and, three sets of farm buildings, in all constituting about 5 percent of the area. These impervious areas tend to increase both the peak rate and total amount of runoff but the small increase in these probably is well within the degree of accuracy obtainable in estimates of runoff from other agricultural watersheds to which these data will be applied. The soils are mainly Tama, Dubuque, and Dodgeville silt loams developed from deep loess and a mixture of loessial material and limestone residuum. These are largely deep and moderately deep, moderately permeable soils capable of absorbing large quantities of water. Twenty acres of the area have been strip cropped on the contour with 100-foot wide strips, for the entire period of record. Fifty-seven acres have been in permanent pasture during this same period.

Watershed W-II (22.8 acres) is a fan-shaped area as shown by the form factor of 1.10. The total difference in elevation from the weir to the highest point in the area is 54 feet. The area has no well-defined waterways and the prevailing slopes of 4 and 8 percent include most of the watershed. The depth to impervious stratum exceeds 48 inches for most of the area. The low number of waterways and the deep permeable soils tend to reduce runoff rates but this is somewhat offset by the shape of the watershed. There are no impervious areas in this watershed. Four acres have been strip cropped on the contour with strips 100 feet wide in a 3-year rotation of corn, grain, and hay.

Watershed W-III with an area of 52.5 acres is approximately twice as long as its average width and has a total difference in elevation of 85 feet. Land slopes vary from 2 to 20 percent with prevailing slopes of 4 and 10 percent each, applying to more than 30 percent of the area. The form factor of 0.46, the number of acres per waterway, 26.2, and the drainage density 44 feet per acre, indicate that with respect to length of overland flow and concentration of runoff, this area is more nearly similar to W-I than W-II. Impervious areas consist of one set of farm buildings and a gravel

road across the area. There are no special conservation measures on the area other than a concrete notch for gully control about 150 feet upstream from the measuring station. There is an area of deposition for 500 feet upstream from the concrete notch with a gradient of 3 percent and an average width of 40 feet where the runoff spreads and infiltrates. This makes the peak rates and total amounts of runoff from the area appear low.

Watershed W-IV is an area of 171 acres fairly similar in shape to W-II but having more clearly defined drainages which are common to the larger areas. The total difference in elevation is 101 feet. The prevailing slopes are 4 and 7 percent, with a maximum slope of 12 percent for a small portion of the area. The form factor of 0.78 indicates an area which is nearly circular. Impervious areas consist of: the blacktop road running north and south through the area; a short section of gravel road, and one set of farm buildings. Soil over most of the area is more than 48 inches deep. Thirteen acres of this area have been strip cropped with 100-foot strips on the contour and a 3-year rotation of corn, grain, hay for the entire period of record. Twenty-two acres have been in permanent pasture during this same period. Most of the remainder of the area is farmed in rectangular-shaped fields with a 3-year rotation of corn, grain, hay.

INSTRUMENTATION AND PROCEDURES

The instrumentation for the runoff studies consists of one runoff and one or more rainfall measuring stations on each watershed and a temperature station for the group.

Each runoff measuring station consists of a triangular broad-crested weir, stilling well, instrument shelter, and outside staff gages. Precalibrated weirs rather than current-meter measurements were used in obtaining runoff records because storm runoff from such small watersheds is flashy; the rates increase from zero to the maximum in a few minutes; the maximum rates are not sustained long enough to permit satisfactory current-meter measurements; and intense storms frequently occur at night. Triangular weirs were used because they give consistent accuracy at all heads, are self-cleaning, fit the topography well with a minimum of temporary pondage, and their rating is not seriously affected by submergence. All weirs have a crest width of 4 inches, which laboratory tests indicated was the minimum for producing a satisfactory rating curve. The side slopes of the weirs are 3 to 1 on the small watersheds W-II and W-III and 5 to 1 on W-I and W-IV. The design capacity of all weirs is more than double the maximum measured in the 9 years of record.

Head over the weirs is measured by water-level recorders which will record unlimited range in stage on a scale of 5 inches of chart equals 1 foot of stage. This is accomplished by using a recorder which reverses the direction of the pen at each foot of stage. The recorder is equipped with an 8-day clock housed in an instrument shelter which is mounted on top of the stilling well. The center of the stilling well is located 10 feet upstream from the center line of the 4-inch surface of the weir crest to be certain the recorder is not affected by drop in the water surface near the weir. The clocks for stations W-II, W-III, and W-IV are geared to make one revolution every 6 hours which gives a time scale of 1 inch equals 25 minutes. The runoff from station W-I extends over a longer period of time and this clock is geared to make one revolution every 12 hours. With these scales, stage can be read to the nearest 0.01 foot and time to the nearest minute.

Each of the water-level recorders is equipped with a stainless steel tape, graduated to 0.01 foot extending over the float wheel and having the float and a counterweight attached to the ends. A small brass hook called the index pointer and used to determine the float-tape reading, is screwed into the floor of the instrument shelter so that the point just misses the float tape. At the time of the initial installation, and twice yearly thereafter, the outside staff-gage reading, chart line, and float-tape readings have been adjusted to agree within 0.005 foot.

Each of the nine rainfall measuring stations consists of a recording, weighing, non-reversing rain gage, equipped with an 8-day cylindrical clock, and a standard United States Weather Bureau gage, this latter being used to check the total catch and operation of the recording mechanism. These gages are located 6 feet center to center and with receiving funnels 3 feet above the ground surface. They are exposed as nearly as possible in accordance with the recommendations of the Subcommittee on Standards of the National Resources Committee. The location of each rainfall station is shown on the topographic map, figure 2, page 5. All recording rain gages, except station R-1, have a recording capacity of 6 inches and a chart scale of 1 inch equals 1 inch of rainfall. The clocks are geared to make one revolution each 12 hours, giving a time scale of 1 inch per hour. With these scales, depth of rainfall can be read to the nearest 0.025 inch, and estimated to 0.01 inch, and time to the nearest minute. Station R-1 has a 6-inch recording capacity and the clock makes one revolution every week.

The temperature station contains one recording hygrothermograph which records the air temperature and relative humidity and a soil thermograph recording the soil temperatures at depths of 6, 12, and 24 inches. One set of Standard Weather Bureau maximum and minimum thermometers is also located at this station and used as a check against the recorded air temperatures. The thermographs and thermometers are housed in a Standard United States Weather Bureau instrument shelter.

All stations are inspected once each week during dry weather. In addition, all rainfall and runoff stations are inspected and charts changed after every rain. Information on the crop cover and tillage conditions is collected immediately after the occurrence of runoff.

Rainfall records are tabulated at each change in slope of the pen trace, and the intensities computed for 5, 10, 15, etc., minutes are the actual maximum rate for the period rather than the rate for the regular clock intervals. A sufficient number of points are selected so that an accurate record of the rainfall can be reproduced from the tabulated values.

Points are selected from the runoff charts at frequent intervals so that a smooth hydrograph may be constructed from the resultant computed rates of runoff. To obtain correct runoff hydrographs, the weir discharge values given in the laboratory-rating tables must be corrected for pondage. The rate of runoff at any instant is equal to the discharge over the weir plus the rate of change in volume of the pond. With the rapid rates of rise to be expected on these watersheds, the rate of ponding at a given instant may be as great or even greater than the discharge over the weir. Pondage-correction curves were prepared by first making an accurate topographic survey of the pond using 0.5-foot contour intervals. The area of the pond in square feet, at any elevation, divided by 60 gives the rate of runoff in cubic feet per second for a rate of change in stage of 1 foot per minute.

METHODS OF ANALYSIS

Rates and amounts of runoff from small agricultural watersheds are affected by rainfall amounts, intensities, and distribution; antecedent moisture conditions; cover and tillage practices; watershed characteristics; and soil type and depth. Because of the large number of variables affecting runoff, it was considered advisable to try to determine the frequency of recurrence of rates of runoff directly rather than relating each peak to rates of rainfall and finally using these relations to determine the frequency of runoff from longer rainfall records. Although data for periods longer than that of record and from watersheds of varying size and cover are essential to accurate analyses, the urgent and immediate need for usable values of rates and amounts of runoff justifies the analysis of the present available records. Design values given in the report should be considered as tentative and subject to revision as additional data become available

Comparison of Rainfall with Long-Time Records

One of the first considerations in the analysis of short records of runoff data is to determine if rainfall amounts and intensities during the period of record agree well with long-time rainfall records. High rates of runoff from small watersheds are caused by intense rainfalls rather than by melting snow or a combination of rainfall and melting snow. Since all of the most intense rainfalls in the area represented by these studies occur from May to September, the comparison of rainfall during this period with long-time Weather Bureau records is more important than comparisons of annual precipitation. Both annual and seasonal comparisons were made with the 56-year Weather Bureau record for Lancaster, Wis. The values for the 9-year period at Fennimore were found to agree closely with those obtained from the long-time record.

Frequency determinations of rainfall intensities for various time periods were made from the 9-year Fennimore record and compared with similar values derived by Yarnell (6) from long-time Weather Bureau records. For this comparison, Yarnell's values were increased by 5 to 10 percent, as recommended by him, because his intensities were determined from the uniform 5-minute intervals published by the Weather Bureau instead of actual maximum values for selected durations. Intensities for the 10-, 30-, and 60-minute periods tested were found to be slightly higher than the adjusted Yarnell values for all recurrence intervals.

Since the intensities for all periods up to 60 minutes were found to be above Yarnell's adjusted values and the total annual and seasonal amounts above the long-time normal, it may be assumed conservatively that the runoff for the 9-year period of record is reasonably representative of longer-time records.

Probability Studies of Peak Rates of Runoff

Probability studies were made to determine the peak rates of runoff that might be expected for various recurrence intervals. These studies were made for the experimental watersheds at La Crosse and Fennimore, and also for all other watersheds within a size range of from 2.3 acres to 257 square miles that have comparable shape, topography, soils, and crop cover.

The relationship between size of watershed and magnitude of peak rate was determined by plotting peak rate for a recurrence interval of once in 10 years against size of watershed for all watersheds that had average cover conditions (fig. 4, p. 14).

The effect of cultivation on the magnitude of peak rates was determined by comparing peak rates from watersheds having different percentages of cultivated area.

RECOMMENDED DESIGN VALUES

Peak Rates for Various Recurrence Intervals

The results of these studies have been incorporated in table 3, page 15, and figures 5 and 6, pages 16 and 17. Table 3 shows the recommended peak rates of runoff for various size drainage areas, and recurrence intervals for three types of cover. Peak rates for 25- and 50-year recurrence intervals are 1.25 and 1.40 times the 10-year values. Figures 5 and 6 show graphically the relation between size of drainage area and rates of runoff for a recurrence interval of once in 50 years. Mixed cover in both tables and figures applies to areas having a cover of one-half corn and grain and one-half hay and pasture. The recommended design values of peak rates of runoff apply only to areas within the soil types listed where the prevailing slopes are from 2 to 10 percent and the range in form factor A/L^2 from 0.5 to 1.0. They have been prepared in a manner to permit their inclusion in engineering handbooks if desired.

Flood-Distribution Graph

Maximum rates of runoff on small watersheds usually last only a very few minutes. For this reason, it is not necessary to provide spillway capacity for the maximum rate to be expected for a given recurrence interval if even a moderate amount of temporary storage is available above the crest of the spillway. Such reduction in rates of runoff is probably not justifiable when the structure is to be designed for a 10-year recurrence interval. In calculating any possible reduction in peak discharge, due to such storage, it is necessary to know the total runoff for the storm and the shape of the inflow hydrograph. A frequency analysis was made on several of the areas, in a manner similar to that used for the peak rates, to determine the total storm runoff for various recurrence intervals. The relationship between total storm runoff for a recurrence interval of once in 50 years and the percent of area cultivated is shown in figure 7, page 18.

Attempts were made to develop flood-distribution graphs for each of the watersheds, using the method suggested by Commons (1). A study of several of the more important hydrographs revealed no fixed relation between times of rise and recession. The location of the peak, with respect to time, seems to vary greatly for these small areas, depending upon the rainfall intensity and distribution within the storm; antecedent moisture; crop cover; and shape of drainage area. The time of rise varied from 3 to 22 percent of the total time base for the 22.8-acre watershed. This variation becomes less as the size of the area increases. Examination of table 6, page 29, also shows there is no fixed relation between peak rates and total storm runoff. Slightly better agreement was obtained by using only those hydrographs resulting from storms of long duration and on the larger areas of 171 and 330 acres. Figure 8, page 19, shows the best average flood-distribution graph which is recommended, for these larger watersheds of 200 acres to 2,000 acres, for use in the general soils and farming area represented by these studies.

When the size of the drainage area and the percent cultivated is known, the 50-year design inflow hydrograph may be computed from the distribution graph shown in figure 8, page 19, (2). First, the peak rate of runoff (Q) is obtained from table 3,

RELATIONSHIP BETWEEN WATERSHED SIZE AND PEAK RATES OF RUNOFF.

Note:– Peak rates of runoff are for a 10-year recurrence interval.

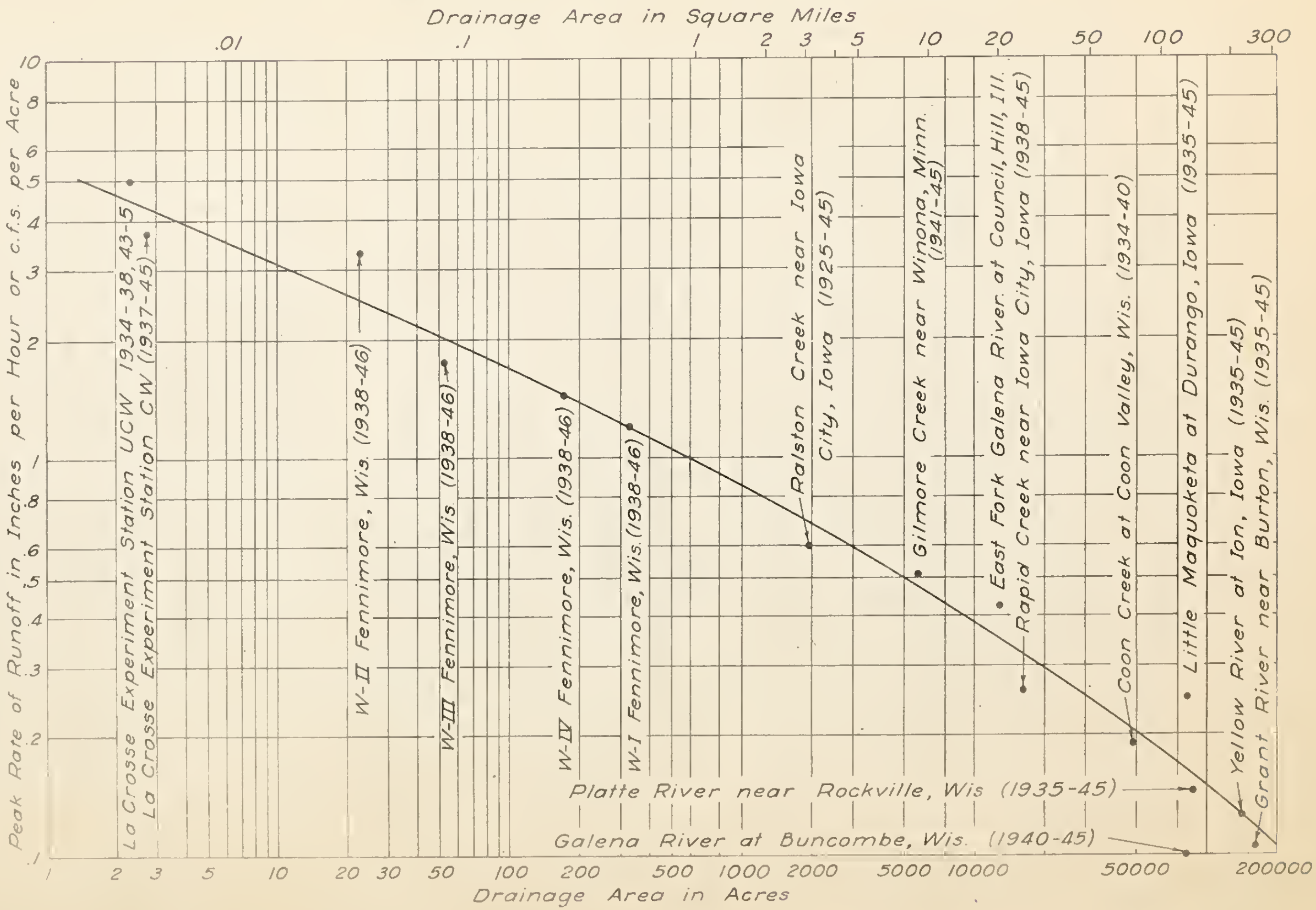


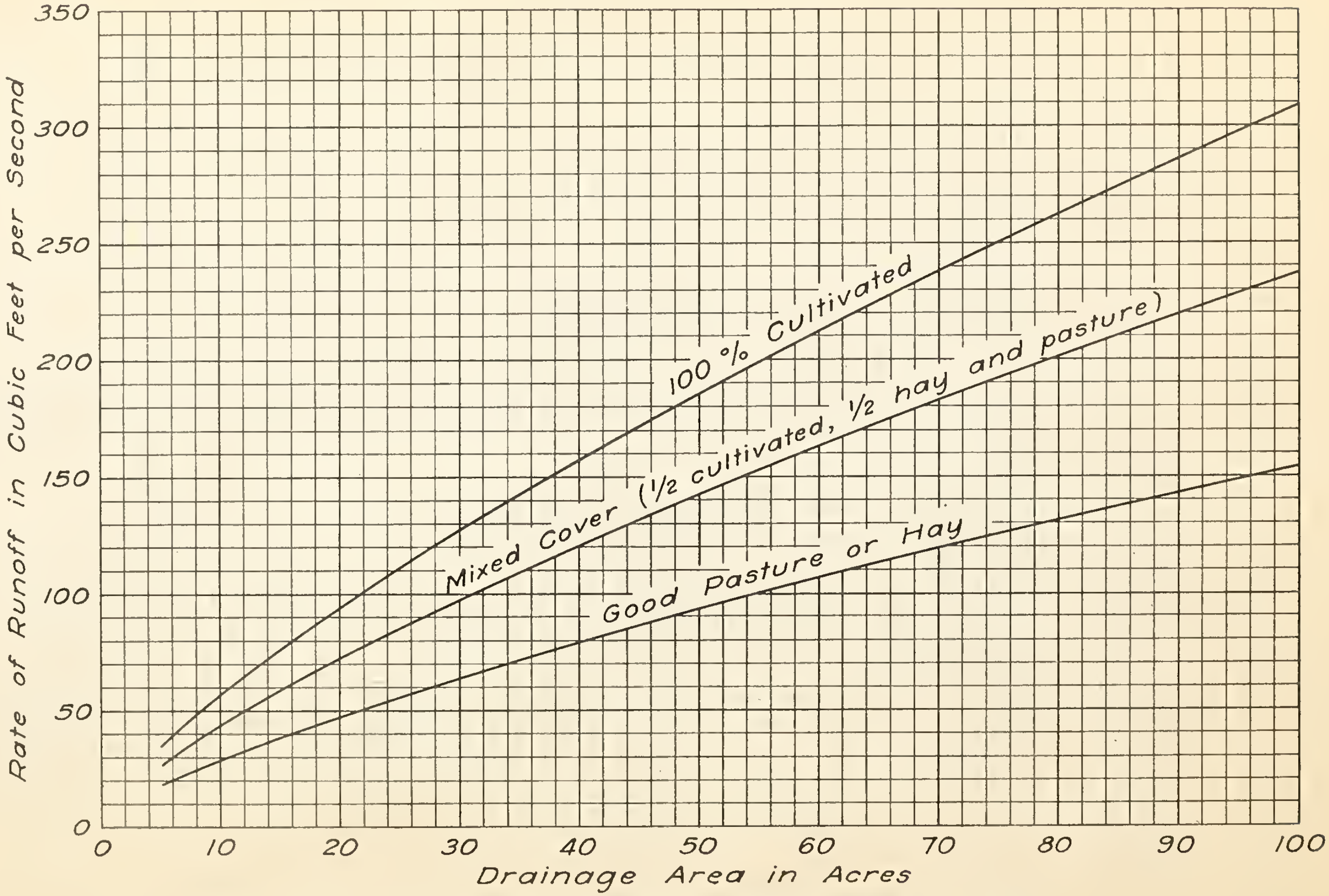
FIGURE 4

TABLE 3.--*Recommended discharge rates in cubic feet per second for various recurrence intervals and cover conditions*

NOTE: These values apply only on deep, medium-textured, moderately permeable, friable silt loams of Tama, Fayette, Dubuque, Dodgeville, Clinton, and related soils with range in prevailing slopes from 2 to 10 percent and form factor, A/L^2, between 0.5 and 1.0.

	10-yr. recurrence interval			25-yr. recurrence interval			50-yr. recurrence interval		
Drainage area in acres	Cultivated	Mixed cover	Good pasture or hay	Cultivated	Mixed cover	Good pasture or hay	Cultivated	Mixed cover	Good pasture or hay
2	12	9	6	15	12	8	17	13	8
5	25	19	12	31	24	16	35	27	18
10	40	31	20	51	39	25	56	43	28
15	55	42	27	69	53	35	77	59	38
20	68	52	34	84	65	42	95	73	47
25	80	62	40	100	77	50	113	87	57
30	91	70	46	113	87	57	128	98	64
40	112	86	56	140	107	70	157	120	78
50	133	102	66	165	127	83	186	143	93
60	152	117	76	190	146	95	213	164	107
70	170	131	85	212	164	107	238	184	120
80	187	144	94	235	180	117	263	202	131
90	205	158	103	256	197	128	287	221	144
100	221	170	110	275	212	138	310	238	155
125		198			247			277	
150		225			280			315	
175		252			315			353	
200		275			345			385	
225		301			375			421	
250		325			405			455	
275		348			435			487	
300		370			460			520	
350		410			510			574	
400		450			560			630	
450		490			612			686	
500		525			660			735	
550		563			705			788	
600		600			750			840	
650		635			795			890	
700		667			830			935	
800		730			910			1,020	
900		792			990			1,110	
1,000		850			1,060			1,190	
1,100		905			1,130			1,265	
1,250		990			1,240			1,385	
1,500		1,125			1,400			1,575	
1,750		1,250			1,560			1,750	
2,000		1,360			1,700			1,900	
2,250		1,485			1,850			2,080	
2,500		1,585			1,980			2,220	
2,750		1,690			2,110			2,365	
3,000		1,800			2,250			2,520	
3,500		1,975			2,470			2,765	
4,000		2,160			2,700			3,025	
4,500		2,340			2,925			3,280	
5,000		2,500			3,125			3,500	

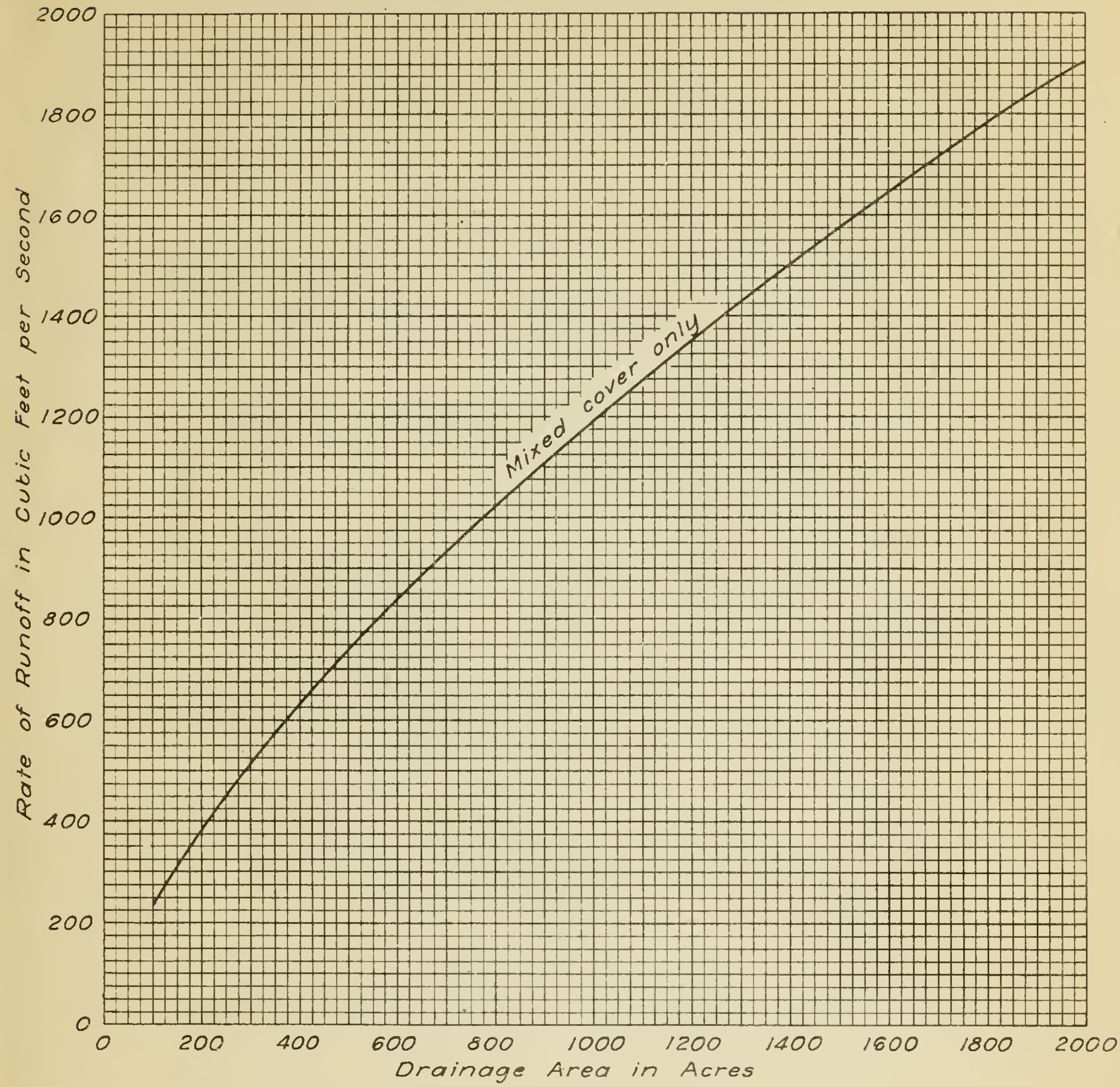
50-YEAR RATES OF RUNOFF FOR THE DESIGN OF CONSERVATION STRUCTURES.



Note – These values apply only to areas having deep, medium textured, moderately permeable, friable silt loams of Tama, Fayette, Dodgeville, Dubuque, Clinton, and related soils, within a range of slopes from 2% to 10% and having a form factor (A/L^2) between 0.5 and 1.0.

FIGURE 5.

50-YEAR RATES OF RUNOFF, FROM AREAS OF 100 TO 2,000 ACRES, FOR THE DESIGN OF CONSERVATION STRUCTURES.



Note – These values apply only to areas having deep, medium textured, maderately permeable, friable silt loams af Tama, Fayette, Dadgeville, Dubuque, Clintan, and related soils, within a range af slopes fram 2% ta 10% and having a form factar (A/L^2) between 0.5 and 1.0.

FIGURE 6.

RELATION BETWEEN 50-YEAR FREQUENCY OF TOTAL RUNOFF AND PERCENT OF DRAINAGE AREA UNDER CULTIVATION.

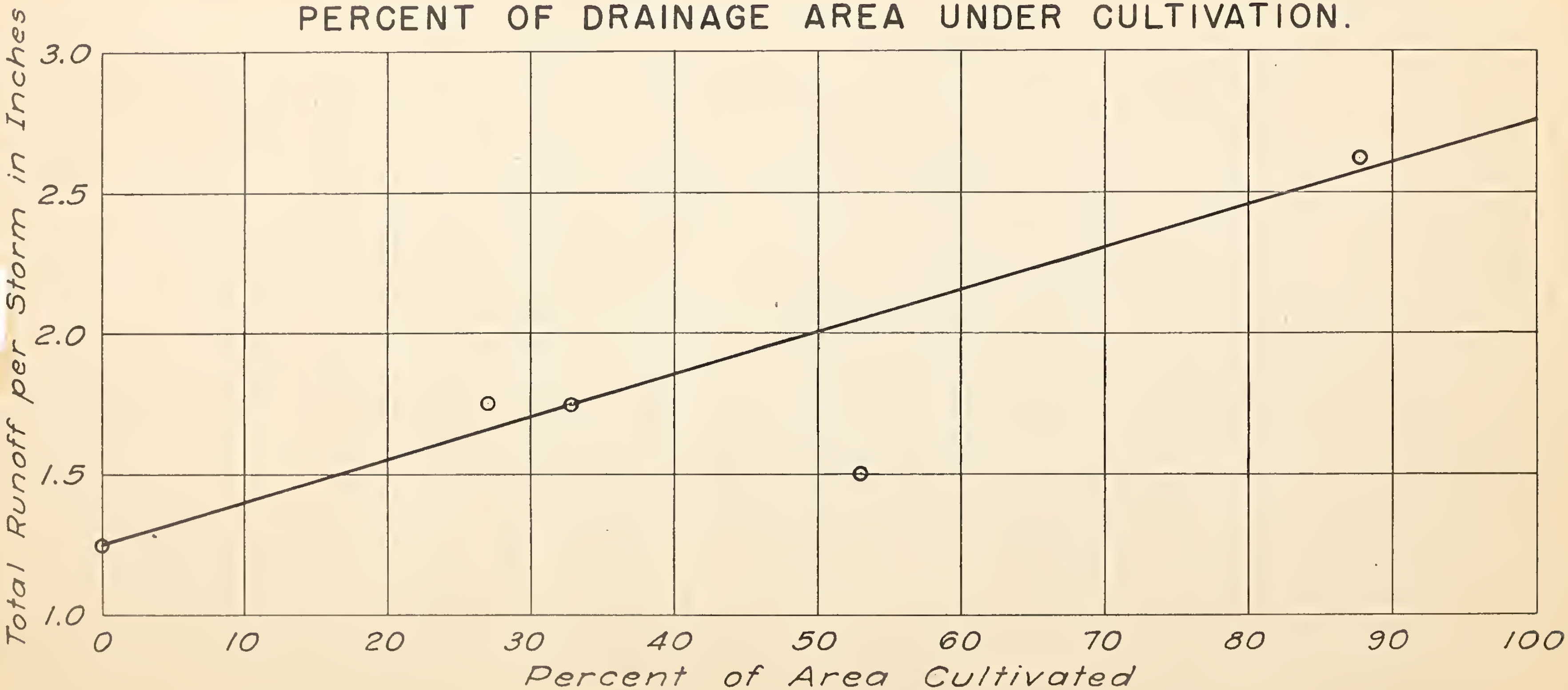
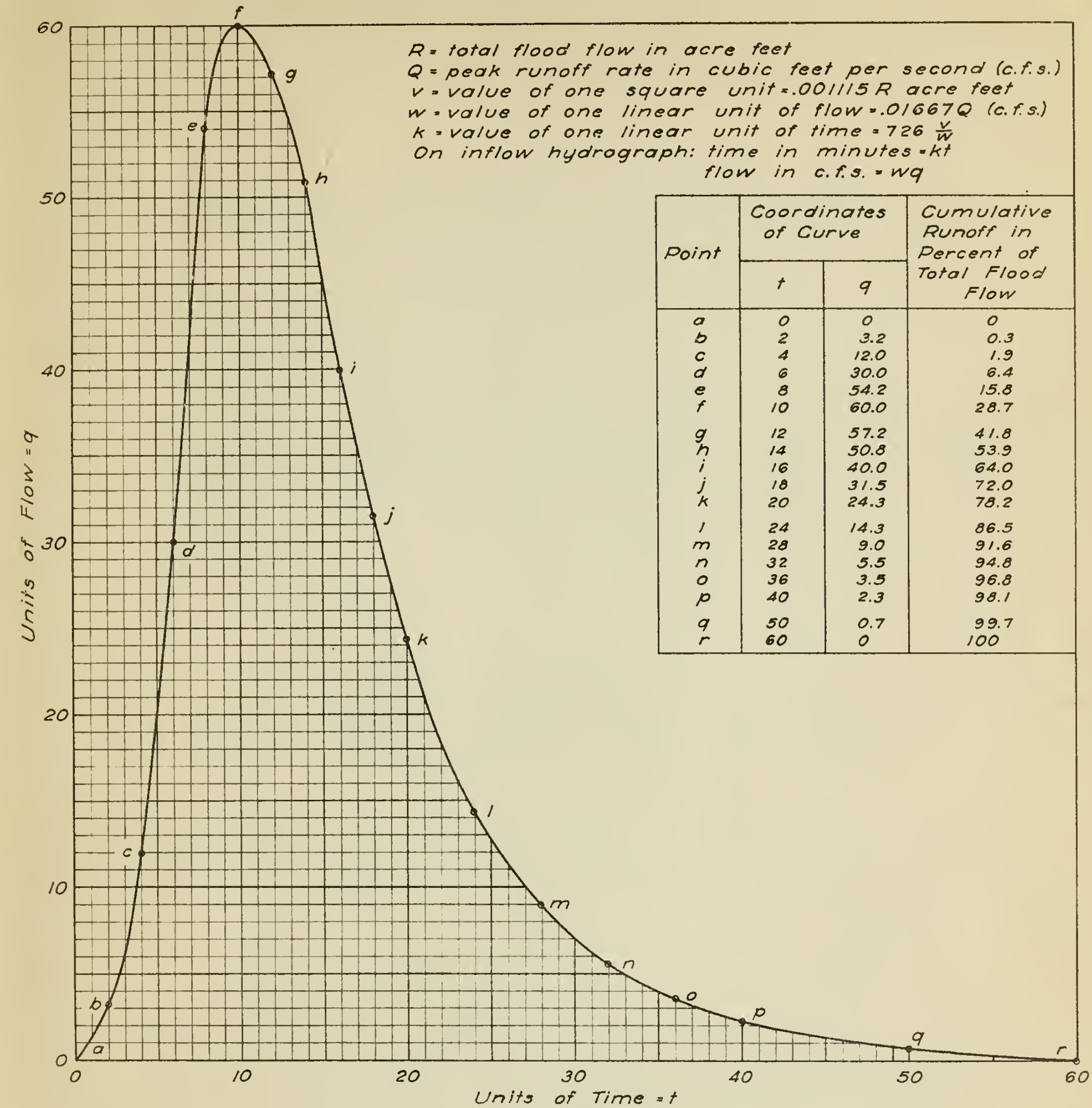


FIGURE 7.

TYPICAL FLOOD DISTRIBUTION GRAPH FOR AGRICULTURAL WATERSHEDS OF 200 TO 2,000 ACRES.



Point	Coordinates of Curve		Cumulative Runoff in Percent of Total Flood Flow
	t	q	
a	0	0	0
b	2	3.2	0.3
c	4	12.0	1.9
d	6	30.0	6.4
e	8	54.2	15.8
f	10	60.0	28.7
g	12	57.2	41.8
h	14	50.8	53.9
i	16	40.0	64.0
j	18	31.5	72.0
k	20	24.3	78.2
l	24	14.3	86.5
m	28	9.0	91.6
n	32	5.5	94.8
o	36	3.5	96.8
p	40	2.3	98.1
q	50	0.7	99.7
r	60	0	100

Note – This graph applies only to areas of deep, medium textured, moderately permeable, friable silt loams of Tama, Fayette, Dodgeville, Dubuque, Clinton, and related soils within a range of slopes of 2% to 10% and having a form factor (A/L^2) between 0.5 and 1.0.

FIGURE 8.

page 15, or from figure 6, page 17. The total runoff in inches is next taken from the curve of figure 7, page 18, and converted to acre-feet (R) by multiplying by the number of acres in the drainage area and dividing by 12.

Let R = total flood runoff in acre-feet
Q = peak rate of runoff in cubic feet per second
v = 1 square unit of volume in acre-feet
w = 1 linear unit of flow in cubic feet per second
k = 1 linear unit of time in minutes

There are about 897 square units, under the flood distribution graph, which represents the total flood flow. Then each square unit (v) must equal ($R \div 897$) or 0.001115R acre-foot. The peak rate of runoff is represented by 60 units of flow. Then one unit of flow (w) equals ($Q \div 60$) or 0.01667Q second-feet. One square unit of flood volume (v), must equal 1 linear unit of flow (w), multiplied by 1 linear unit of time (k), with a factor to make the units consistent.

Then

$$v \text{ acre-feet} = w \frac{\text{ft}^3}{\text{sec}} \times k \text{ min} \times \frac{60 \text{ sec/min}}{43560 \frac{\text{ft}^3}{\text{ac.ft.}}} = \frac{60 \text{ wk ac. ft.}}{43560}$$

Therefore k equals

$$k = \frac{43560}{60} \frac{v}{w} = 726 \frac{v}{w}$$

Example: Given a 200-acre mixed cover watershed, compute the design inflow hydrograph for a frequency of once in 50 years. From table 3 or figure 6 the peak rate of runoff (Q) is 385 c. f. s. and from figure 7 the total flood flow for 50 percent cultivated is 2 inches or 33.33 acre-feet.

Then

$$v = 0.001115 \times 33.33 = 0.03715 \text{ acre-foot.}$$

$$w = 0.01667 \times 385 = 6.42 \text{ c. f. s.}$$

$$k = 726 \times \frac{0.03715}{6.42} = 4.2 \text{ min.}$$

Table 4, page 22, gives the computed coordinates which are necessary to draw the design inflow hydrograph. The required capacity of any control structure can be obtained from the design inflow hydrograph modified by the flood storage as computed by flood routing methods.

Conclusions

The following conclusions are intended to apply only to the soils named and within the boundaries of the area shown in figure 1, page 2.

1. Rainfall intensities and amounts during the period of record of these studies appear to be representative of longer term records within the area shown.

2. Determination of runoff frequencies directly, without regard to the factors producing them, is feasible but only in cases where each of these factors represents a true sample of a longer period of record.

3. Good vegetal cover is very effective in reducing rates of runoff from small watersheds in the soil types included in this report.

4. There is a definite relation between peak rates of runoff and size of drainage area for a given recurrence interval, if the variation in cover, soils, erosion, topography, and shape of drainage area is held within reasonable limits.

5. The flood distribution graph presented is probably a good average graph for areas of from 200 to 2,000 acres of the soil groups included in this report. Considerable variation in its shape will be found for individual storms on smaller drainage areas.

FACTORS AFFECTING RATES OF SURFACE RUNOFF

Crop Cover

Crop cover has a marked effect on rates of runoff from these soils. Table 5, page 23, shows the crop cover, in percent of area, on each of the watersheds for all the years of record. It will be noted that cover conditions have remained reasonably uniform on the two larger areas but show a wide variation on the smaller watersheds.

Since none of these watersheds is under one type of cover, the only possibility of evaluating effect of cover on rates and amounts of runoff is to compare hydrographs of two or more storms having as near the same rainfall intensities and antecedent moisture conditions as possible. It is necessary to select only storms of very high intensities for such comparisons because of the ability of these soils, under favorable conditions, to absorb large amounts of precipitation in a very short time. By using two watersheds, one with the same percentages of crops for each storm and the other having a wide difference in cover it is possible to reduce any differences due to soil moisture and the effect of variation in height of vegetal cover. With these limitations

TABLE 4--*50-year hydrograph for 200 acres mixed cover*

Flood distribution graph			Design inflow hydrograph	
	Coordinates		Coordinates	
Point	*t*.	*q*	Time minutes *kt*.	Flow c. f. s. *wq*
a	0	0	0	0
b	2	3.2	8.4	21
c	4	12.0	16.8	76
d	6	30.0	25.2	192
e	8	54.2	33.6	348
f	10	60.0	42.0	385
g	12	57.2	50.4	367
h	14	50.8	58.8	326
i	16	40.0	67.2	257
J	18	31.5	75.6	202
k	20	24.3	84.0	156
l	24	14.3	100.8	92
m	28	9.0	117.5	58
n	32	5.5	134.3	35
o	36	3.5	151.1	22
p	40	2.3	168.0	15
q	50	.7	210	5
r	60	0	252	0

TABLE 5.--*Vegetative cover on the Fennimore, Wis., watersheds in percent of drainage area*

W-I = 330 ACRES

Year	Corn	Small grain	Hay	Pasture	Building and roads
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1938	24.7	21.1	30.3	18.4	5.5
1939	31.1	17.8	28.4	17.2	5.5
1940	18.9	24.0	30.5	21.1	5.5
1941	23.0	17.7	34.3	19.5	5.5
1942	19.9	15.7	32.1	26.8	5.5
1943	28.5	11.6	31.4	23.0	5.5
1944	31.9	18.1	24.6	19.9	5.5
1945	32.6	21.9	21.7	18.3	5.5
1946	23.4	25.8	24.1	21.2	5.5

W-II = 22.8 ACRES

Year	Corn	Small grain	Hay	Pasture	Building and roads
1938	6.9	34.5	58.6		
1939	34.5	26.0	39.5		
1940	23.5	24.2	52.3		
1941	34.3	4.1	61.6		
1942	6.4	34.3	59.3		
1943	24.0	2.9	73.1		
1944	51.3	7.9	40.8		
1945	15.5	46.2	38.3		
1946	6.0	26.1	67.9		

W-III = 52.5 ACRES

Year	Corn	Small grain	Hay	Pasture	Building and roads
1938	32.5	5.2	32.2	22.8	7.3
1939	24.2	18.7	27.0	22,8	7.3
1940	11.6	20.2	38.1	22.8	7.3
1941	22.6	28.0	12.1	30.1	7.3
1942	8.7	19.3	30.6	36.0	7.3
1943	19.3	7.8	29.2	36.4	7.3
1944	37.0	3.4	23.8	28.6	7.3
1945	25.7	23.7	15.5	27.8	7.3
1946	4.7	24.7	34.6	28.7	7.3

W-IV = 171 ACRES

Year	Corn	Small grain	Hay	Pasture	Building and roads
1938	31.7	22.4	27.0	13.2	5.7
1939	41.7	19.2	20.5	12.9	5.7
1940	24.7	31.8	19.4	18.4	5.7
1941	30.2	15.8	35.4	12.9	5.7
1942	26.9	13.3	31.4	22.7	5.7
1943	34.6	11.9	29.9	17.9	5.7
1944	35.4	22.7	20.5	15.7	5.7
1945	38.3	20.6	22.5	12.9	5.7
1946	32.5	26.0	23.1	12.7	5.7

in mind, only the storms of August 12, 1943, and July 11, 1944, can be used for this comparison. Any possible effect, due to differences in soil types and shape of the areas, can be minimized by comparing W-I with W-III and W-II with W-IV. Storms were placed with the beginning of intense rainfall on the same time line to give an indication of the relative position of peaks.

Figure 9, page 25, shows the comparison of these storms on W-I and W-III. W-I had nearly the same amount of corn in 1943 and 1944, but the 1944 corn acreage on W-III was double that of 1943. The rainfall intensities of the August 12, 1943, storm were higher and came later in the storm pattern than for the July 11, 1944, storm. Antecedent moisture was very low for the 15 days prior to these storms, but the one on August 12, 1943, had over 1.00 inch in the 3 hours before the intense portion, whereas the one on July 11, 1944, had the highest intensities at the beginning of the storm. One other difference, not apparent from these data, was that the precipitation in June 1944 was 8.22 inches, which resulted in excellent pasture and hay whereas the rainfall for the same length of time before the August 12 storm was only 3.38 inches, leaving the pastures short and dry. These differences should have about the same effect on both the areas. The effect of these differences in antecedent moisture and vegetative cover is readily apparent in the runoff hydrographs for W-I. The peak rate of runoff on W-I was three times as high on August 12, 1943, as on July 11, 1944, but the ratio of the peaks on W-III was only 1.7 to 1. This shows that much of the effect of rainfall intensities and other conditions which caused the wide differences in runoff on W-I is offset by the change in acreage of corn on W-III. Average infiltration rate during both these storms was more than 3 inches per hour, showing that these soils are capable of absorbing large amounts of rainfall at high intensities when in a dry condition and with good vegetal cover.

Figure 10, page 26, shows graphically the comparison of the August 12, 1943, and July 11, 1944, storms on W-II and W-IV. Watershed W-IV, which also had an equal corn acreage both years, shows about the same ratio (3 to 1) between peak rates as for W-I. The ratio of peaks for these storms on W-II was 1 to 7.4 which means that even the higher intensities of the August 12 storm were more than offset by other factors. The only explanation for W-II showing such a great difference from the other three watersheds for the August 12, 1943, storm is that there was no pasture and the 73 percent in hay afforded excellent cover. The corn acreage for 1944 on W-II was more than double that of 1943 and most of this large corn acreage was replanted during the last week of June. This combination of conditions on W-II greatly magnified rates of runoff on July 11, 1944, while holding down those of August 12, 1943. Average infiltration rates on W-II appear to be about 2.5 inches per hour on July 11, 1944, and 4.0 on August 12, 1943.

Antecedent Moisture

Figure 11, page 27, shows a graph of three storms and the resultant runoff hydrographs on W-IV for which the rainfall intensities and amounts and the vegetal cover are similar but have different antecedent moisture conditions. All of these storms were placed with the beginning of intense rainfall on the same time line to give a better picture of the relative position of runoff peaks. The 10-minute intensities of these storms are approximately equal, yet they show a wide difference in peak rates and amounts of runoff. Both the June 3, 1943, and June 22, 1944, storms had their highest intensities early in the storm period, but the first of these was preceded by a rainfall of 2.15 inches in the previous 24 hours while the latter had only 0.10 inch in a 5-day period. The June 28, 1945, storm had the lowest rainfall intensities but they came

ACCUMULATED PRECIPITATION AND RUNOFF HYDROGRAPHS FOR WATERSHEDS W-I AND W-III.

FIGURE 9.

ACCUMULATED PRECIPITATION AND RUNOFF HYDROGRAPHS
FOR WATERSHEDS W-II AND IV.

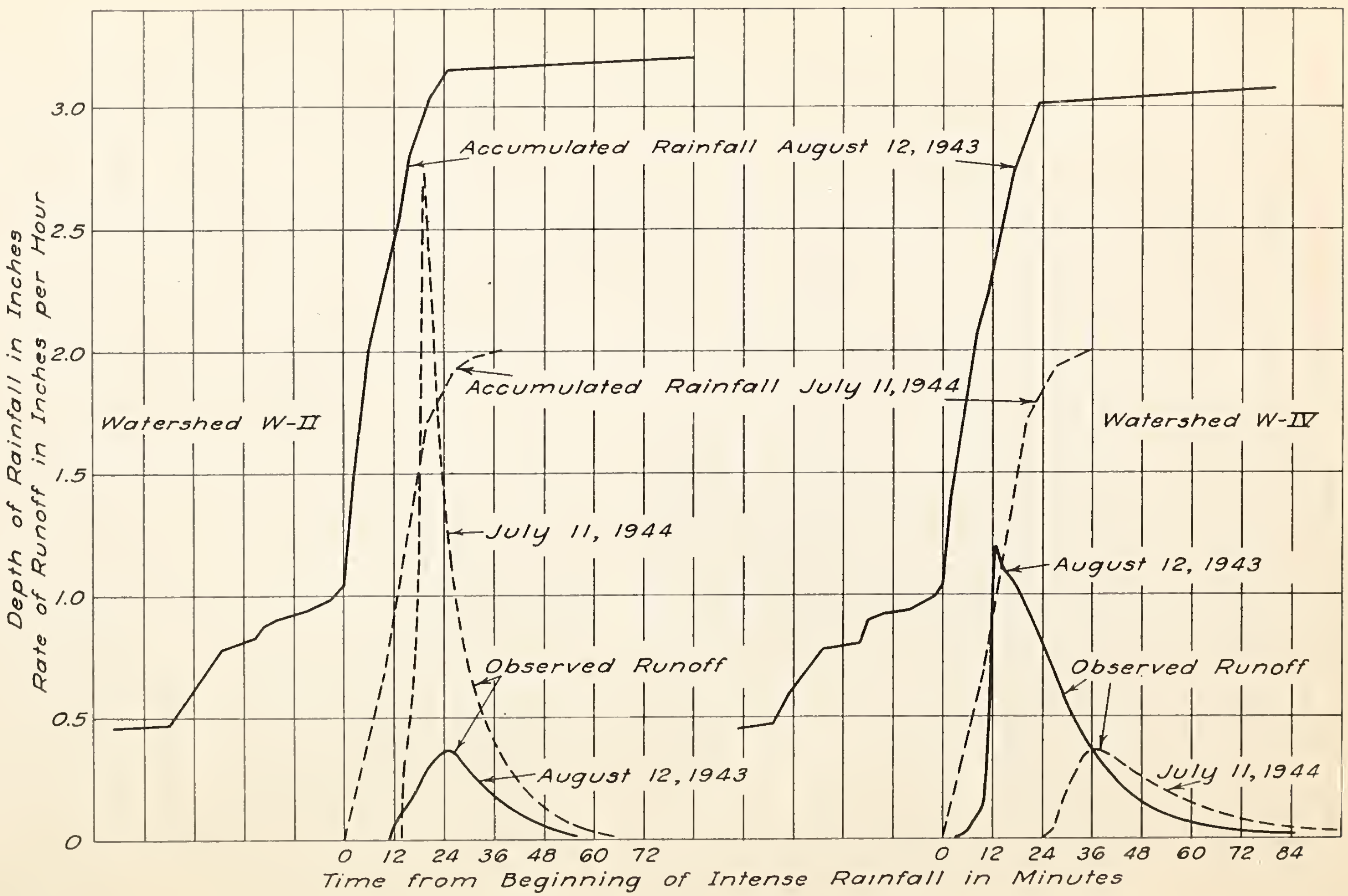


FIGURE 10.

ACCUMULATED PRECIPITATION AND RUNOFF HYDROGRAPHS FOR THREE STORMS ON WATERSHED, W-IV.

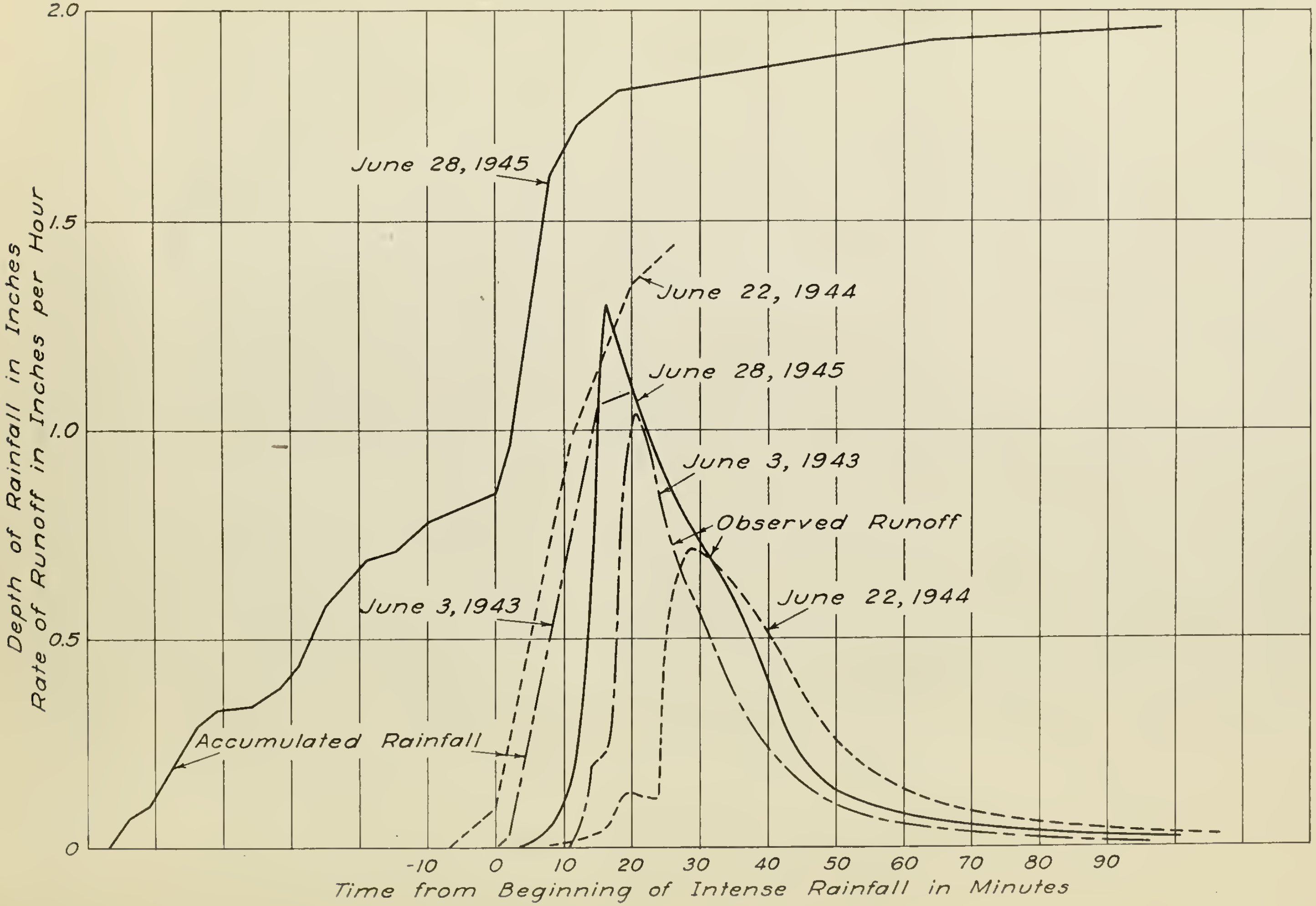


FIGURE 11.

after 0.84 inch in the first hour and gave higher rates and amounts of runoff than either of the other storms. The vegetal cover is about the same for these storms and, therefore, the differences in runoff must be largely due to the antecedent moisture condition.

Comparisons for Selected Storms

Table 6, page 29, shows the precipitation, runoff, antecedent moisture, and vegetal cover for selected storms on each of the four watersheds. Frequently, short excessive rates of precipitation have caused no runoff from these areas. If the intensity of precipitation was the sole factor in producing rates of runoff, then the storm of August 12, 1943, should have given the highest rates of runoff for the entire period for all areas. Examination of the table shows that the storm of June 28, 1945, with considerably lower rainfall intensities, gave higher rates of runoff from all areas than the August 12, 1943, storm. The chief difference in these two storms appears to be antecedent moisture conditions, there being only 0.75 inch of precipitation in the 4 weeks prior to August 12, 1943, as compared with 4.90 inches for a similar period before June 28, 1945. Both storms had about 1.0 inch of rainfall before the intense part began. The great differences between the peak rates of runoff for these storms on W-II are due largely to differences in vegetal cover.

The 15-minute rainfall intensities and vegetal cover on W-III for the storms of June 22, 1944, and June 28, 1945, are comparable, yet the peak rate and total runoff for the latter are considerably higher. Precipitation for the 3 weeks prior to June 22, 1944, was 6.4 inches as against 3.10 inches for a like period before the June 28, 1945, storm. The effect of the 1 inch of rainfall in the hour immediately preceding the intense part of the June 28 storm is apparent. In the case of the June 28, 1945, storm, plant interception and surface detention were already accounted for and the infiltration rate was greatly reduced before the beginning of the period of intense rainfall.

Examination of table 6, page 29, and figure 11, page 27, shows that, although antecedent moisture and rainfall intensities are not identical, the same general relationships hold in comparing the storms of June 3, 1943, and June 22, 1944, as for August 12, 1943, and July 11, 1944.

TABLE 6.--*Comparative data for selected storms on the Fennimore, Wis., watersheds*

Date	Total rainfall Inches	Duration of storm Hrs.	Duration of storm Min.	Total runoff inches	Percent runoff	Previous rainfall total for No. of days - inches: 1 da.	3 da.	5 da.	10 da.	15 da.	Rainfall before intense part of storm: Amount Inches	Duration Hrs.	Duration Min.	Rainfall intensities Inches per hr. for— 10 min.	15 min.	20 min.	30 min.	Vegetative cover percent of area: corn	Small grain	hay	pasture	Peak rate of runoff In/hr.	Runoff as % intense rainfall
WATERSHED W-I = 330 ACRES																							
7/26/40	4.94	14	45	0.83	16.8	0.37	0.37	0.37	0.37	1.24	1.91	11	00	3.90	3.00	2.79	2.88	18.9	24.0	30.5	21.1	0.87	28.6
8/ 3/40	2.30	0	54	.40	17.4	.10	.48	.63	5.98	5.98	0	0	0	4.32	4.28	4.14	3.64	18.9	24.0	30.5	21.1	.77	17.4
6/ 3/43	1.05	0	18	.26	24.8	2.10	2.65	3.05	3.30	3.54	0	0	0	4.50	4.04	3.15	2.10	28.5	11.6	31.4	23.0	.62	24.8
8/12/43	3.50	5	30	.46	13.1	0	.20	.20	.36	.56	1.12	3	20	7.50	6.80	5.88	4.30	28.5	11.6	31.4	23.0	.91	22.3
6/17/44	1.08	0	37	.33	30.6	.35	1.10	2.95	4.28	4.49	0	0	0	2.88	2.08	1.86	1.92	31.9	18.1	24.6	19.9	.44	33.0
6/22/44	1.53	0	34	.40	26.1	.10	.10	.10	3.95	5.30	0	0	0	4.80	4.40	3.80	2.86	31.9	18.1	24.6	19.9	.51	28.6
7/11/44	1.95	0	34	.27	13.8	0	0	0	0	.29	0	0	0	6.00	5.40	5.10	3.88	31.9	18.1	24.6	19.9	.30	14.2
6/ 1/45	1.34	1	43	.36	26.9	.68	.92	2.09	2.66	3.31	.06	0	25	2.58	2.16	1.86	1.42	32.6	21.9	21.7	18.3	.54	30.5
6/28/45	2.04	2	37	.49	24.0	.22	.27	1.22	1.22	2.40	.92	1	0	4.92	3.76	2.91	2.18	32.6	21.9	21.7	18.3	1.01	50.0
WATERSHED W-II=22.8 ACRES																							
7/26/40	4.84	14	45	.43	8.9	.38	.38	.38	.38	1.22	1.82	11	0	4.02	3.36	3.18	3.24	23.5	24.2	52.3		.79	14.8
8/ 3/40	2.38	0	57	.32	13.4	.10	.53	.67	5.85	5.85	0	0	0	4.82	4.72	4.38	3.74	23.5	24.2	52.3		1.03	16.4
6/ 3/43	1.05	0	18	.13	12.4	2.09	2.61	3.00	3.25	3.50	0	0	0	4.50	4.04	3.15	2.10	24.0	2.9	73.1		.84	12.4
8/12/43	3.45	5	30	.14	4.1	0	.16	.16	.28	.46	1.05	3	19	7.50	6.56	5.85	4.36	24.0	2.9	73.1		.37	6.7
6/17/44	1.11	0	37	.46	41.4	.38	1.15	2.99	4.41	4.59	0	0	0	3.12	2.16	2.19	2.12	51.3	7.9	40.8		1.34	43.4
6/22/44	1.55	0	33	.54	34.8	.06	.06	.06	4.16	5.65	0	0	0	5.52	4.68	4.02	3.00	51.3	7.9	40.8		2.74	40.9
7/11/44	2.00	0	34	.46	23.0	0	0	0	0	.28	0	0	0	6.00	5.44	5.16	3.92	51.3	7.9	40.8		2.74	23.7
6/ 1/45	1.40	1	37	.41	29.3	.71	1.00	2.26	2.82	3.29	.08	0	30	2.70	2.24	1.94	1.44	15.5	46.2	38.3		.95	35.7
6/28/45	2.07	2	30	.61	29.0	.25	.30	1.20	1.20	2.48	.96	1	0	5.10	3.80	3.06	2.20	15.5	46.2	38.3		2.68	62.0
WATERSHED W-III = 52.5 ACRES																							
7/26/40	4.76	14	45	.52	10.9	.38	.38	.38	.38	1.23	1.74	11	0	4.08	3.32	3.18	3.24	11.6	20.2	38.1	22.8	.80	17.9
8/ 3/40	2.30	0	55	.26	11.3	.10	.52	.69	5.84	5.84	0	0	0	4.32	4.40	4.16	3.64	11.6	20.2	38.1	22.8	.69	12.7
6/ 3/43	1.04	0	19	.17	16.3	2.16	2.73	3.16	3.39	3.66	0	0	0	4.50	3.92	3.12	2.08	19.3	7.8	29.2	36.4	.76	16.3
8/12/43	3.60	5	30	.38	10.6	0	.20	.20	.37	.56	1.05	3	19	8.10	7.00	6.15	4.66	19.3	7.8	29.2	36.4	1.13	16.9
6/17/44	1.16	0	38	.35	30.1	.35	1.10	2.95	4.27	4.43	0	0	0	3.12	2.28	2.43	2.16	37.0	3.4	23.8	28.6	.97	33.0
6/22/44	1.51	0	34	.30	19.9	0	0	0	3.97	5.43	0	0	0	5.04	4.40	3.78	2.92	37.0	3.4	23.8	28.6	1.23	20.0
7/11/44	1.99	0	46	.15	7.5	0	0	0	0	.28	0	0	0	6.06	5.48	4.80	3.78	37.0	3.4	23.8	28.6	.67	7.9
6/ 1/45	1.38	1	40	.19	13.8	.75	.95	2.27	2.79	3.24	.07	0	30	2.82	2.08	1.77	1.32	25.7	23.7	15.5	27.8	.35	11.3
6/28/45	2.15	2	35	.39	18.1	.21	.26	1.17	1.17	2.35	1.01	1	0	5.28	3.92	3.06	2.24	25.7	23.7	15.5	27.8	1.63	35.5
WATERSHED W-IV = 171 ACRES																							
7/26/40	4.94	14	45	.96	19.4	.40	.40	.40	.40	1.24	1.91	11	0	3.84	3.08	2.88	2.90	24.7	31.8	19.4	18.4	1.01	33.1
8/ 3/40	2.34	0	53	.50	21.4	.10	.45	.58	6.04	6.04	0	0	0	4.74	4.40	4.44	3.80	24.7	31.8	19.4	18.4	.95	23.1
6/ 3/43	1.10	0	23	.31	28.2	2.15	2.64	3.02	3.30	3.53	0	0	0	4.92	4.24	3.24	2.20	34.6	11.9	29.9	17.9	1.05	28.2
8/12/43	3.30	5	30	.43	13.0	0	.21	.21	.37	.56	1.04	3	20	6.90	6.00	5.46	4.12	34.6	11.9	29.9	17.9	1.21	22.0
6/17/44	1.00	0	33	.29	29.0	.32	1.07	2.94	4.38	4.59	0	0	0	2.88	2.08	1.86	1.92	35.4	22.7	20.5	15.7	.53	30.8
6/22/44	1.44	0	32	.33	22.9	.10	.10	.10	3.85	5.17	0	0	0	4.56	4.20	3.78	2.74	35.4	22.7	20.5	15.7	.72	22.9
7/11/44	2.01	0	37	.19	9.5	0	0	0	0	.31	0	0	0	6.00	5.36	5.13	3.92	35.4	22.7	20.5	15.7	.37	9.8
6/ 1/45	1.40	1	40	.36	25.7	.72	.92	2.14	2.66	3.14	.07	0	30	2.82	2.32	1.98	1.46	38.3	20.6	22.5	12.9	.54	28.8
6/28/45	1.96	2	35	.47	24.0	.21	.25	1.23	1.23	2.43	.84	0	56	4.92	3.68	2.94	2.12	38.3	20.6	22.5	12.9	1.31	48.4
3/ 5/46	1.10	6	50	.86	78.2	Ground frozen and bare								.66	.56	.52	.48	Ground frozen				.33	78.2

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